SOUTHWEST RESEARCH INSTITUTE ASSISTANCE TO NASA IN BIOMEDICAL AREAS OF THE TECNOLOGY UTILIZATION PROGRAM

QUARTERLY PROGRESS REPORT #1

Period Covered: 1 February 1969 - 30 April 1969

Contract No. NASW-1867

SwRI Project No. 13-2538

Prepared for

Chief, Dissemination Branch, Code (UT)
Technology Utilization Division
Office of Technology Utilization
NASA
Washington, D. C. 20546

15 May 1969

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO HOUSTON

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Prepared by: Louis S. Berger
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A. INTRODUCTION

1. General

The aeronautical and space activities conducted by the National Aeronautics and Space Administration (NASA) are creating an impressive body of knowledge of great potential scientific and technological usefulness. In carrying out its congressional mandate to disseminate this information for ultimate benefit of the general public, NASA has engaged in an extensive publications program; in particular, publications under the auspices of NASA's Technology Utilization Division (TUD) are specifically aimed at expeditiously transferring NASA developments to the scientific and industrial community.

Special difficulties are encountered when it is attempted to transfer NASA-derived technology, by means of TUD publications alone, to scientists in the biomedical fields. These scientists are particularly overburdened by the copious amounts of published biomedical material; additionally, they are by and large unfamiliar with the language and symbology of the physical and engineering sciences. As a result, technology in physical science and engineering has often not been as effectively transferred to biomedical applications as it deserves to be.

The TUD's investigations of the chain of events leading to the introduction of new products, technological inventions, and methods into medical practice have suggested that the biomedical research teams at medical schools and similar biomedical research institutions play a key role in this process. New discoveries, introduced by these groups, tend to proceed naturally through stages of professional approval, manufacturing interest and participation, on to the level of the practicing physicians, bringing direct health benefits to the public. It would seem an attractive goal to introduce NASA-derived advances at the level of the biomedical research team, and thus to utilize the existing channels to the medical practitioner and his patients for effective technological transfer.

As a result of these investigations, NASA's TUD has developed a general methodology for the solution of this important and special technological transfer problem. Prominently included in this methodology was the establishment of several strategically placed Biomedical Application Teams consisting of appropriately cross-trained and broadly experienced physical and biological scientists. It is the task of the Biomedical Application Team to facilitate and improve the productive interaction between NASA centers and biomedical research teams. Emphasis is on interpersonal contact, in which the cross-trained members of the Biomedical Application Team form an active link between these two groups of scientists. A flexible system is

maturing in which both principal groups, NASA personnel and biomedical researchers, freely and effectively participate in mutually beneficial exchange of skills and knowledge.

2. Participating Personnel

The following scientists are participating in the program:

- Southwest Research Institute Biomedical Application Team
- Southwest Research Institute Personnel:
  - Ray W. Ware, M.D., Director
  - Louis S. Berger, Project Manager
  - Raul San Martin, M.D.
  - Charles J. Laenger, Sr.
  - Robert J. Crosby
  - Chester A. Heath
  - Samuel G. Schiflett
  - W. R. Brian Caruth
  - Rufus H. Holloway
  - Andre G. Buck
- Key Coordinators at User Institutions:
  - F. Hermann Rudenberg, Ph.D., Associate Professor, Department of Physiology, The University of Texas Medical Branch, Galveston, Texas
  - Jack B. Johnson, Chief, Biomedical Instrumentation Section, Southern Research Support Center, Veterans Administration, Little Rock, Arkansas
  - Mr. John Hall, Seattle Handicapped Center, Seattle, Washington
  - Mr. Don Baker, University of Washington, Department of Bioengineering, Seattle, Washington
  - Mr. H. A. Miller, Stanford University School of Medicine
  - N. P. Thompson, M.D., Palo Alto Medical Research Foundation
  - Marcus J. Fuhrer, Ph.D., Departments of Physical Medicine and Rehabilitation, Texas Institute for Rehabilitation and Research
  - V. Mooney, M.D., (SRS), Rancho Los Amigos Hospital, Downey, California

B. SUMMARY OF PROJECT ACTIVITY, METHODOLOGY, INTERFACES

The project work during the first quarter concentrated on improving of the program methodology and on an extensive review of all active problems.

Methodological improvements covered the following subject areas.

1. Project record keeping procedures were streamlined; a significant amount of personnel time was invested in developing formal procedures for recording all significant phases of project activity, both for fiscal reporting purposes and for securing of narrative data. The stimuli for this activity came from several sources: (a) Our sponsor indicated his reporting requirements in detail; (b) the operation analysis of the program, which was reported in the last final report (31 December 1968) pointed the way to a better definition of the specific data required for analysis purposes and also indicated how a technique for collecting the data could be developed; (c) project performance had matured to the stage where the various project activities could be realistically and meaningfully categorized.

2. On the basis of past experience, it was decided to seek user evaluations in face-to-face interviews, rather than by attempting to elicit the information with standardized record forms.

3. Another important methodological change was development of a more formal procedure for accepting, for actual processing, the problems that had been submitted by researchers. We took care to brief potential Problem Originators, to acquaint them with circumstances surrounding problem submissions; we emphasized that problem submission did not guarantee that a problem would be accepted for actual processing, but that submitted problems would receive very careful consideration and scrutiny, and would be acted upon subsequently. Criteria for problem acceptance, which in the past had been implicit in project performance, were made explicit for internal project use. These criteria concerned the areas of Problem Originator resources; problem definition; redundancy; problem scope and size; and considerations relating to past experience, for a given researcher, of the productivity of the researcher/team interaction. It is expected that the more formal analysis and processing of newly submitted problems prior to initial disposition will ultimately benefit all the participants in the experimental program: the sponsor, the users, the user institutions, and the Application Team.

As a result of problem consolidation, over 50 problems have been closed out over the past six months: 23 remain active. In the current

. Other Southwest Research Institute Staff consulted:

- Leon M. Adams, Ph.D., Manager, Organic and Polymer Chemistry
- Wallace L. Anderson, Ph.D., Senior Research Engineer
- Robert Bond, Ph.D., Senior Research Physicist
- Robert E. Engelhardt, Senior Research Engineer
- Roger H. Hemion, Manager, Transportation Research Section

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reporting period, two new problems have been accepted, one problem has been returned to the Problem Originator with explanation of why it was found to be unsuitable for processing at this time, and nine potential new problems have been discussed by Team members during various visits to user institutions.

The Teams participated in 9 visits to user institutions, visited 4 NASA Research Centers, and attended 2 project meetings with the sponsor.

In this year's project mission, the Biomedical Application Program methodology will be applied to a public sector, namely, Automotive Safety. The sponsor is in the process of formalizing arrangements with the cognizant government agencies. In addition, exploratory meetings were held between members of the Application Team and the Texas Highway Department, and also members of the Highway Research Board.

C. PROBLEM STATUS SUMMARY

1. Transfers

HUV-18 "Microanalysis of Mucous-Secreting Cells" This has been identified as a transfer. A transfer report is appended.

2. Problems Inactivated

HUV-10	"Instrumented Prosthetic Leg" Problem Originator has taken his problem to a university researcher, who has provided a solution.
HUV-16	"Novel Joint Design Applied to Assistive Devices for Human Limbs" Problem Originator's grant application was not approved; he therefore is unable to pursue the problem further at this time.
GLM-4	"Implanted Blood Pressure Transducer" Problem Originator is using a commercial device. Capacitance transducer turned up by search not commercially available and likely to be too expensive.
GLM-5	"Chronic Intracranial Pressure Measurement in Man" Problem Originator is using a commercial device. Capacitance transducer turned up by search not commercially available and likely to be too expensive.
GLM-6	"A Model Vascular System" Problem Originator does not have the technical support required to use sophisticated results of the search. He is too lacking in time and interest for us to help to simplify the search results further.
GLM-7	"Viscosity Measurement of Minute Samples of Blood" Lack of time and interest on the part of Problem Originator to pursue the solutions suggested by the search results.
GLM-8	"Computer Program for Electroencephalograph: Period Analysis" Lack of time, funds and interest to buy a TIME DATA-100 or similar real-time spectrum analyzer.
GLM-10	"Computer Program for Flame Spectrophotometry" Lack of time and interest to pursue solution suggested by NASA Team member (Dr. Gardner) in the analysis of the problem which was made while the Team member was preparing a Problem Abstract.

GLM-12 "Computer Selection and Elimination of Artifacts"
Problem Originator is no longer at Galveston and is now in a different field of research.

GLM-13 "Multiple Cospectral Density Analysis of Time-Service Data"
Problem Originator is no longer at Galveston and is now in a different field of research.

GLM-18 "Ultramicro Methods for Analyzing Biological Specimens"
Problem Originator lacks the time to pursue the problem.

RNV-5 "Pressure Measurement to Aid Prevention of New Decubitus Ulcers"
Problem Originator is proceeding with his own design solution.

RNV-11 "Measurement and Telemetry of Kinesiology of Handicapped Patients"
Transfer complete. (They will purchase a device from Whittaker, a production copy of NASA/Ames 5-channel Telemetry device.)

RNV-16 "Patient Breathing Monitor"
Transfer complete. Negotiation for commercial device in progress.

RNV-17 "The Effect of Oxygen Poisoning on Biological Systems"
Adequate information available in open literature; Problem Originator referred to proper sources.

SFM-1 "Automatic EKG-Time Interval Measurement"
Desired techniques are beyond state-of-the-art.

SFM-2 "Automatic Techniques for Smoothing Blood Pressure Waveforms"
Desired techniques are beyond state-of-the-art.

SFM-4 "Early Detection of Vestibular Unbalance in Children"
Transfer completed.

PLR-1 "Measurement of Outer- and Inner- Diameter of Blood Vessels"
Desired technology has been judged to be beyond the current state-of-the-art.

PLR-3 "Automatic Control of Therapeutic Agents"
No significant work in this field has been revealed by any search procedures.

PLR-4 "Exercise Tests for Detection of Heart Disease"
Useful literature search, but no direct application of the material is envisioned by Problem Originator.

WMS-4 "Simultaneous Multistress Effects on the Cardiovascular System"
Transfer complete.

NWR-1 "Motion Pattern Measurement of Patients"
Project requirements have changed - a new researcher is now responsible for the problem.

3. Active Problems - Status

HUV-1 "Reduced Workload Environment for Physically Handicapped Patients"
Transfer in progress: documentation continues.

HUV-17 "Automatic Remote Human Movement Analysis"
Problem Abstract Draft completed.

HUV-18 "Microanalysis of Mucous-Secreting Cells"
Transfer; transfer report submitted; transfer documentation in progress.

GLM-3 "Determination of Local Blood Flow, Blood Gas Concentration, and Blood pH in Small Portion of an Organ"
Problem Abstract Draft completed.

GLM-9 "Measurement of Local Tissue Oxygen Consumption, In Vivo"
Problem Abstract Draft completed.

GLM-14 "Repetitive Measurement of Kidney Mass in Intact Animal"
Problem Abstract Draft modified in response to recommendations of Problem Originator. Draft revision completed.

GLM-15 "Respiration Volume and Rate Measurements in Unencumbered (Free) Child"
Negative evaluation of NASA-ERC sensor has been received from the Problem Originator; Problem Abstract Draft has been prepared.

GLM-16 "In-Situ Tumor Mass Determination on Rat Leg"
Problem Abstract Draft prepared.

GLM-17 "Respiratory Gases Measurement"
Consultant has been informed of the non-availability of metabolic rate sensors at NASA/Edwards (by Dr. Lewis); consultant is checking with Dr. C. Berry at MSC on availability of suitable sensors.

GLM-19 "Measurement of the Velocity of Myocardial Contractions by Noninvasive Means"
First draft of Problem Abstract completed and sent to Problem Originator for critical review. Improved draft is in progress.

GLM-20	"Lymphocyte Destruction Under Sterile Conditions" New problem; problem search statement in preparation.
SNM-1	"Enhancement of X-Ray Contrast Study Films" Problem Originator is preparing new material for submission to JPL under a recently established grant.
RNV-10	"Sensors for Measuring Foot-Floor Impact Forces" Awaiting grant support; no current activity.
RNV-12	"Body Temperature Regulation in Congenital Amputees" Transfer in progress. New Problem Originator is taking over research (original Problem Originator is leaving).
RNV-13	"Improved Laryngoscope for Use in Disabled Children" Potential transfer; two potential development and manufacturing sources were located, one through the NASA search, the other by Mr. Berger (NASA Team member) and NASA/Ames (Mr. B. Beam) independently. Contract to build is in negotiation.
RNV-14	"Materials for Prevention of New Decubitus Ulcers" Abstract Draft prepared.
RNV-15	"Rapid Multiple Gas Measurement for Medicine" Search evaluation is in progress; four documents ordered for study 14 April 1969.
SFM-3	"Improved Monitoring of Heart Cell Contraction Parameters" Laboratory facility is being activated; potential transfer of sensor and cardiotachometer technology revealed during Team member's facility visit 27 March 1969.
WSM-1	"Ultrasonic Coupling Techniques" Problem Abstract Draft completed.
NWR-5	"Numerical Methods for Solutions to Wave Equations in Layered Media of Arbitrary Cross Section" Problem Abstract Draft completed.

NWR-6	"The Effects of Electromagnetic and Acoustic Fields on Living Organisms" Grant applications prepared, using search as basis. A completely successful search, according to Problem Originator evaluation.
SRS-8A	"Acquisition and Telemetry of Heart Rate, Blood Pressure and Blood Flow in Free-Ranging Dogs" Problem Originator is selecting additional articles for ordering. Preliminary tests are in progress, and it is requested that this problem be kept active.
SRS-8B	"Methods of Signal Categorization" Search completed; problem originator has not yet had an opportunity to screen and use the citations.

4. Active Abstracts

Problem Abstract Drafts have been submitted to NASA Headquarters during the past reporting period on the following active problems:

WSM-1	Ultrasonic Coupling Techniques
SRS-8B	Methods of Signal Categorization
HUV-17	Automatic Remote Human Movement Analysis
NWR-5	Numerical Methods for Solutions to Wave Equations in Layered Media of Arbitrary Cross Section
RNV-14	Materials for Prevention of New Decubitus Ulcers
GLM-3	Determination of Local Blood Flow, Blood Gas Concentration, and Blood pH in Small Portion of an Organ
GLM-9	Measurement of Local Tissue Oxygen Consumption, In Vivo
GLM-14	Repetitive Measurement of Kidney Mass in Intact Animal
GLM-15	Respiration Volume and Rate Measurements in Unencumbered (Free) Child
GLM-16	In-Situ Tumor Mass Determination on Rat Leg
GLM-19	Measurement of the Velocity of Myocardial Contractions by Noninvasive Means

(A total of 11 Abstract Drafts were prepared in the past quarter.)

D. PARTICIPATION IN SYMPOSIUMS AND MEETINGS

Mr. L. Berger attended the Sixth Space Congress (Theme: Space Technology and Society) and presented a paper which is included as Appendix B in this report.

E. COMMERCIAL PRODUCT AND/OR APPLICATION ENGINEERING ACTIVITY RESULTING FROM TEAM OPERATIONS

One of the submitted problems, RNV-13, "Improved Laryngoscope," appears to be on the threshold of generating engineering/development activity. Two sources of potential solution have resulted from the Biomedical Application Program activity. The Problem Originator is currently investigating both these sources and is expecting submission of formal proposals from at least one source on the subject problem. Secondly, while performing activities not directly connected with the Application Program, Southwest Research Institute staff members realized that certain technological developments had great potential for application to a commercial problem under investigation by an industrial organization. The company representative's attention was called to the NASA technology; plans to apply the Biomedical Application Team's NASA experience to this technological development are currently being explored by the industrial concern.

F. INSIGHTS AND CONCLUSIONS

Significant project insights are implicit in the new methodology described in Section A of this report. Other current insights are presented in the technical paper of Appendix B.

G. PLANS FOR FOLLOWING QUARTER

Management level visits are planned to three user institutions and also to a minimum of four medical and dental institutions in the Southwest who appear to be promising candidates for project participation. It is expected that an improved technique for briefing potential participants will be developed jointly by the sponsor and Southwest Research Institute staff.

We plan to include in our analysis of project performance an analysis to evaluate the effects of changing our formal approach in the areas discussed in Section B: the procedure for new problem acceptance, and the face-to-face interview technique for obtaining project evaluations from problem originators.

During the performance of this year's effort, we plan to develop a document, using the operations research procedural instruments as an aid, which will detail the methodology followed by the Team during the current year.

We intend to publish quarterly supplements to the quarterly progress reports; these supplements will contain the full narrative case history material.

We plan to begin a concentrated effort on the public sector portion of the program as soon as our sponsor has completed arrangements with the cognizant agencies.

APPENDIX A.

Transfer Report

Transfer Description

Problem Code: HUV-18

Problem Title: Microanalysis of Mucus Secreting Cells

Problem Originator: Mr. Robert Doggett

Institution : Texas Institute for Rehabilitation and Research

Biomedical Application Team Members
Responsible for Problem: Robert J. Crosby, Charles J. Laenger, Samuel G. Schiflett

Date Problem Acquired: October 30, 1968
Date Transfer Made: March 1969
Elapsed Time to Complete: 5 months

Description of Problem:

Little is known about the basic etiology of cystic fibrosis (CF). Five percent of the people in the U.S. carry this recessive gene! One out of every one thousand babies born in America are afflicted with CF. Mr. Robert Doggett wished to find a technique for analyzing the chemical constitutents of microscopic portions of mucous-secreting salivary gland cell specimens from cystic fibrosis patients. The secretions of patients with this condition are known to be high in sodium compared to a "normal" patient. The abnormally high sodium concentrations form a basis for a screening test to detect the disease in its early stages.

Description of Solution and Source(s):

Investigators in the growing field of microanalyzers have pioneered in producing the scanning electron microscope and microprobe. The electron probe has the unique capability of performing chemical analysis on a micron scale by analyzing the emitted x-radiation generated by an electron beam. Because of its unique ability to analyze specimens of considerable thickness, Mr. Doggett envisioned the effectiveness of the instrument in cystic fibrosis research.

Mr. Doggett stated to Mr. Bob Crosby that he was most interested in using the electron probe analyzer and scope at the NASA Manned

Spacecraft Center. Dr. Ray Ware telephoned Mr. Albert C. Copeland, Quality Assurance Division, on 4 November 1968 and made official arrangements for Mr. Doggett to utilize the NASA facilities.

Searching Method(s): WESRAC search results for GLM-18, "Ultramicro Methods for Analyzing Biological Specimens," were evaluated by the Problem Originator. Mr. Doggett indicated that references pertaining to the scanning electron microscope/probe were current and helpful.

Benefits (Potential and Actual): The exchange of knowledge and maximum use of MSC facilities has reduced duplicity of effort in overlapping areas of research. The early diagnosis of cystic fibrosis is imperative for effective therapy. If the electron microscope/probe can be used to rapidly detect abnormality in biochemical structures and functions that are symptomatic of cystic fibrosis, then every child subjected to the diagnostic test would benefit.

Consultants: Dr. Ray Ware (SwRI) and Dr. Craig Fisher, Head of Clinical Pathology Lab (MSC)

Cost/Effort:

Professional man-hours - 13
Estimated dollar cost - $250 (assigned specifically to problem)

Comments:

The encouraging preliminary results achieved with NASA's scanning of electron microscope may lead to successful early screening of CF. Savings in dollars, man-hours and other resources are impossible to estimate. However, application of the S.E.M. to CF detection simply could not have been performed without NASA's contribution, at this time nor in the near future, because such equipment is not available in this part of the U.S.

Mr. Doggett explained that his association with Dr. Craig Fisher at MSC and 8 hours per week use of the scanning electron micro-probe have been an invaluable asset in determining the feasibility of his approach of detecting CF in infants.

APPENDIX B.

Interdisciplinary Dissemination of Aerospace Technology - A Holistic Approach

INTERDISCIPLINARY DISSEMINATION OF AEROSPACE TECHNOLOGY - A HOLISTIC APPROACH

Louis S. Berger
Southwest Research Institute
San Antonio, Texas

For presentation at the Sixth Space Congress
Cocoa Beach, Florida
17-19 March, 1969

INTERDISCIPLINARY DISSEMINATION OF AEROSPACE TECHNOLOGY - A HOLISTIC APPROACH

Louis S. Berger
Southwest Research Institute
San Antonio, Texas

The ideas which I should like to present were stimulated by the tasks posed to us as members of a Biomedical Application Team sponsored through NASA's Technology Utilization Program. It therefore is appropriate to set the stage by a brief description of the Biomedical Application Program's goals and methodology. These NASA programs were established at three institutions, Midwest Research Institute, Research Triangle Institute, and Southwest Research Institute, to help bring about a highly desirable but difficult to accomplish aim, namely, to transfer applicable aerospace generated research products to the field of biomedicine. Suitable ideas, concepts, techniques and designs were to be sought in all varieties of aerospace research programs. It was an important premise of the project that the quest for biomedically useful technology not be restricted within biologically oriented research programs. That is, our special challenge was to locate biomedically applicable technology among the products of research carried on in areas which might at first glance seem to be totally unrelated to biology. Indeed, relevant research was on occasion discovered in remote technological areas. For example, one of the research hospitals associated with our project is currently engaged in an extensive program to evaluate clinical applications of a device originally developed at Langley Research Center as a reduced (lunar) gravity simulator.

This somewhat unusual "information retrieval" project task has forced us to grapple with fundamental problems in information science. We have accordingly been encouraged by our sponsor to spend a modest proportion of project time on basic studies in this area, and this paper reflects the results of our analyses.

A starting point for our discussion is the thesis that the unexamined, uncritical usage of words may cause extensive and unrecognized mischief. We grow up immersed in our language; it is so much a part of us that, to some extent at least, we are unable to recognize that it significantly affects the way we perceive the world.

For example, a recent journal article[1] explores the way in which we perceive color. As might be expected, different cultures have different names for the various colors. Perhaps more surprising is the impact on the perception of these various color names: the differences in verbal labels induce the members of various societies to perceive colors in different categories—they carve up the visible spectrum in different ways. Not only do the color boundaries occur at different spectral locations, but the number of distinct colors that are recognized varies from culture to culture.

There is by now a substantial literature in the theoretical discipline of general sematics which amplifies this idea; several standard references are listed at the end of the paper.

It may not yet be apparent how this discussion relates to the problem of transferring of information. Perhaps the relevance can be revealed by posing some familiar questions in the conventional way, and then trying to

see to what extent we have prejudged the possible answers by our mode of questioning. Here are the questions in their customary form: What are the problems of transferring information? What is information? How do you store it? How do you retrieve it? And how do you properly describe the information content of a document?

In the light of the comments on the effects of language on perception, let up stop and look at the ways we have worded the problems. Isn't it possible that some of the difficulties of information transfer are due to the word ("information") that is used and in the "thingness" that it implies? Consider these comments by Bois[2]

> "The main trouble is that we often believe that what is going on is what we say is going on. It works fairly well in simple cases, but it often creates unnecessary problems. The hidden implications of what we say cause us to look for things that are not there. Poincare gives an example which has become classical: In the days when very few chemical elements were known, scientists were trying to isolate the element heat. Why did they look for heat as an element comparable to sulphur, oxygen, or mercury? Because it has a name that belonged grammatically (and therefore logically) to the same class as that of elements, the class of nouns or substantives. By implication, substantives referred to substances (or elements), and consequently, the scientists were looking for the substance heat, or phlogiston. But it was not there. Back of that substantive was a process, not a permanent element like sulphur, oxygen, or mercury. What the language said and implied was not what was going on."

Applying this point of view to our problem area, let us then assume that the word "information" has the same limited reality as does the word "phlogiston." If this assumption has merit, it is possible then that we may be misled by accepting the reality of the entity of "information" without reservation: If it is a thing, something that the seeker of "information" is looking for, it should be extractable from documents, be capable of being labeled, stored, retrieved, packaged, and delivered to the consumer. We also are led to ask questions such as: Who is best qualified to perform the various operations of extracting, storing, and retrieving it? What sort of systems and subsystems should we use to carry out the various subtasks which "obviously" need to be carried out? These are some of the questions raised if we ascribe material reality to the apparently innocuous word "information."

In addition, these kinds of questions even imply along what lines the systems which handle information should be designed: the notion in the documentation sciences that information is a thing which can be packaged and transported from originator to ultimate consumer suggests that information systems be designed around the traditional model of a goods transportation system: it suggests that a system which handles information be like other delivery or distribution systems, essentially unidirectional, designed to handle packaged goods which remain invariant while they are being maneuvered through the various way stations of the delivery (and storage) process.

This traditional notion of information has been useful, but we believe that the time has come to consider an alternative description and structuring of the "information transfer" activities: we propose to view the so-called

exchange of information as an overall communications process, involving the originator of thoughts and "facts," various stages of symbolization and transformation of the originator's initial thinking, perception, and experience, and finally involving a user who must deal with some aspect of the symbolic communication. This reformulation in focusing on the communication aspect of the process provides a fresh basis for locating the true difficulties of the process and, at the same time, suggests new approaches to old difficulties.

When we approach the "handling of information" as a problem in communication, our familiarity with impediments to the communication process in other contexts immediately can be applied here to reveal and define problem areas. For instance, since the area of symbolism is a notoriously troublesome one in the general field of communication, we would expect it to be a source of difficulty here also. In addition, we would expect to find problems related to the inevitable entropy-like deterioration of the original communication each time it is retranscribed: the symbols refer to broader and broader categories, and the specific structure of the original communication continually is degraded in this retranslation. We would also expect to encounter special problems when attempting "information transfer" across disciplines—in addition to the well-known language barriers, we would also anticipate communication barriers stemming from different professional backgrounds with their concomitant differences in attitudes, values, and problem solving techniques[3]. Yet another problem area revealed by the communication approach is the area of constraints associated with the

communication channels; we would expect that certain intrinsic features of a channel such as its single mode capability might impede the communication flow. As these examples show, the communication viewpoint is useful in structuring new problem areas.

A second significant advantage of this point of view for the information sciences is that we may expect to obtain help from disciplines that study communication. We would use the models, techniques, and insights achieved by social scientists, logicians, and others engaged in the study of communication processes to generate new approaches which would facilitate the exchange of knowledge. To cite a few examples:

We learn[4] that good communication thrives on dialogue. We would therefore expect to derive extensive benefits from providing a system which somehow incorporated bidirectional communication channels.

Another feature of good communication is multi-modality. We therefore might consider using systems with parallel information channels, perhaps providing a combination of the traditional written form of notational mode together with an audio or video channel.

Incidentally, to refer once again to the NASA Biomedical Application Programs, I might mention that as we have been forced to cope with novel "information exchange" situations in these programs, we have intuitively gravitated toward the techniques just mentioned. For instance, we are beginning to experiment with some multi-modal documents as possible replacements for the more traditional written document.

Finally I should like to suggest that some of the questions which have been mentioned here might with profit be investigated in more detail. First, how can communication be improved, and which disciplines should be consulted for guidance in this area? Secondly, how can we better define and cope with the problems related to the symbolism which is interwoven with the communication process? Third, how can we help the user of the system—the seeker of knowledge—to efficiently and effectively structure his quest? Finally, what are the systems implications of viewing the process as one of communication? Can we develop unique types of systems for the various different kinds of communication exchanges which we encounter in the information sciences? It is hoped that these speculations and thoughts will suggest additional new approaches to the traditional formulation of the "information transfer" problems and that the reformulations which follow from the new point of view will ultimately lead to solutions to some old problems.

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